Tri-gas Pressurization System Testing and Modeling for Cryogenic Applications

B. Taylor, R. Polsgrove, J. Stephens, and A. Hedayat

NASA MSFC, Main Propulsion Systems Branch

Huntsville, AL 35812

Abstract

The use of Tri-gas in rocket propulsion systems is somewhat of a new technology. This paper defines Tri-gas as a mixture of gases composed largely of helium with a small percentage of a stoichiometric mixture of hydrogen and oxygen. When exposed to a catalyst the hydrogen and oxygen in the mixture combusts, significantly raising the temperature of the mixture. The increase in enthalpy resulting from the combustion process significantly decreases the required quantity of gas needed to pressurize the ullage of the vehicle propellant tanks. The objective of this effort was to better understand the operating characteristics of Tri-gas in a pressurization system with low temperature applications. In conjunction with ongoing programs at NASA Marshall Space Flight Center, an effort has been undertaken to evaluate the operating characteristics of Tri-gas through modeling and bench testing. Through improved understanding of the operating characteristics, the risk of using this new technology in a launch vehicle propulsion system was reduced.

Bench testing of Tri-gas was a multistep process that targeted gas characteristics and performance aspects that pose a risk to application in a pressurization system. Pressurization systems are vital to propulsion system performance. Keeping a target ullage pressure in propulsions tanks is necessary to supply propellant at the conditions and flow rates required to maintain desired engine functionality. The first component of testing consisted of sampling Tri-gas sources that had been stagnant for various lengths of time in order to determine the rate at which stratification takes place. Second, a bench test was set up in which Tri-gas was sent through a catalyst bed. This test was designed to evaluate the performance characteristics of Tri-gas, under low temperature inlet temperatures, in a flight-like catalyst bed reactor. The third, most complex, test examined the performance characteristics of Tri-gas at low temperature temperatures in a test configuration built to more closely resemble a vehicle pressurization system. The results of these bench tests address various risks that all relate to underperformance of Tri-gas pressurization systems. .

Generalized Fluid System Simulation Program (GFSSP), an in-house general-purpose fluid system analyzer computer program, was utilized to model and simulate each test. The GFSSP is a general-purpose computer program for analyzing steady state and time-dependent flow rates, pressures,

temperatures, and concentrations in a complex flow network. GFSSP employs a finite volume formulation of mass, momentum, and energy conservation equations in conjunction with the thermodynamic equations of state for real fluids. The system of equations describing the fluid network is solved by a hybrid numerical method that is a combination of the Newton-Raphson and successive substitution methods. The temperature and the pressure changes across each component are computed and compared with the test data. The modeling description and the results for each test series will be presented in the final paper.

The modeling and bench test work described in detail in this paper assists in improving understanding of the use of Tri-gas in flight pressurization systems. By having gained experience working with Tri-gas and having developed an improved understanding of the performance characteristics of the gas mixture, the risk of using it on board a launch vehicle or spacecraft as a part of a propulsion system was significantly reduced. The results and conclusions of this study will benefit the use of Tri-gas in future flight pressurization systems.